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Storrie et al.

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(54) **LINEAR POSITION SENSOR WITH ANTI-ROTATION DEVICE**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 508 days.

This patent is subject to a terminal disclaimer.

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Related U.S. Application Data

(63) Continuation of application No. 12/592,170, filed on Nov. 20, 2009, now Pat. No. 8,400,142.

(51) **Int. Cl.**

G01B 7/14	(2006.01)
G01D 3/028	(2006.01)
G01D 5/14	(2006.01)
G01D 11/16	(2006.01)
G01D 11/24	(2006.01)

(52) **U.S. Cl.**

CPC ***G01D 3/028*** (2013.01); ***G01B 7/14*** (2013.01); ***G01D 5/145*** (2013.01); ***G01D 11/16*** (2013.01); ***G01D 11/245*** (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

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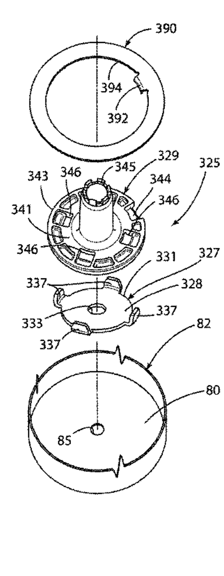
(57) **ABSTRACT**

A sensor used to sense the position of an attached movable object. The sensor can be mounted to a pneumatic actuator. The sensor includes a housing that has a pair of cavities or pockets separated by a wall. A magnet carrier is positioned within one of the cavities and a magnet is coupled to the magnet carrier. The magnet carrier is coupled to the moveable object. A magnetic sensor is positioned in the other of the cavities. The magnetic sensor generates an electrical signal that is indicative of a position of the movable object.

4 Claims, 12 Drawing Sheets



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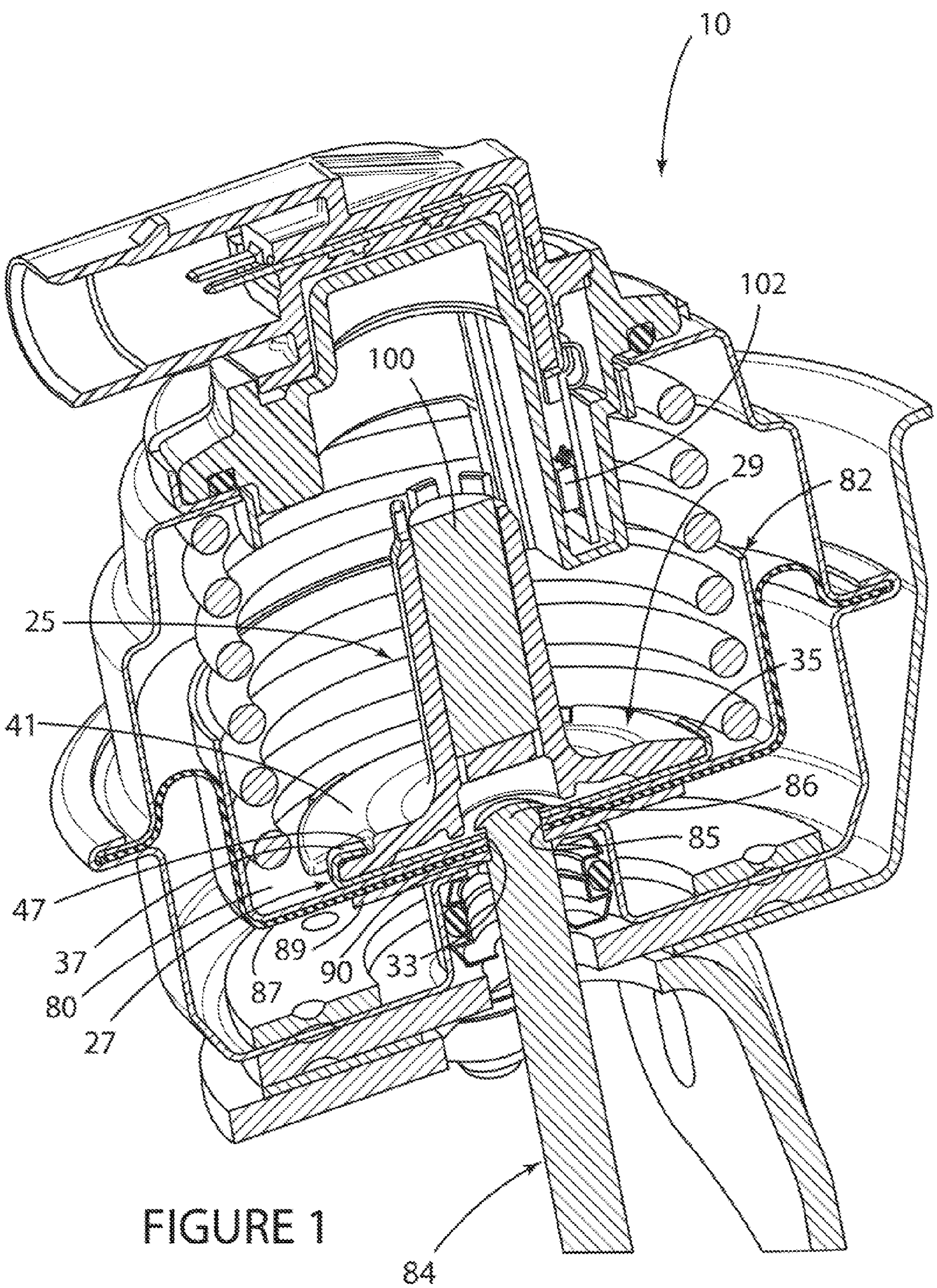

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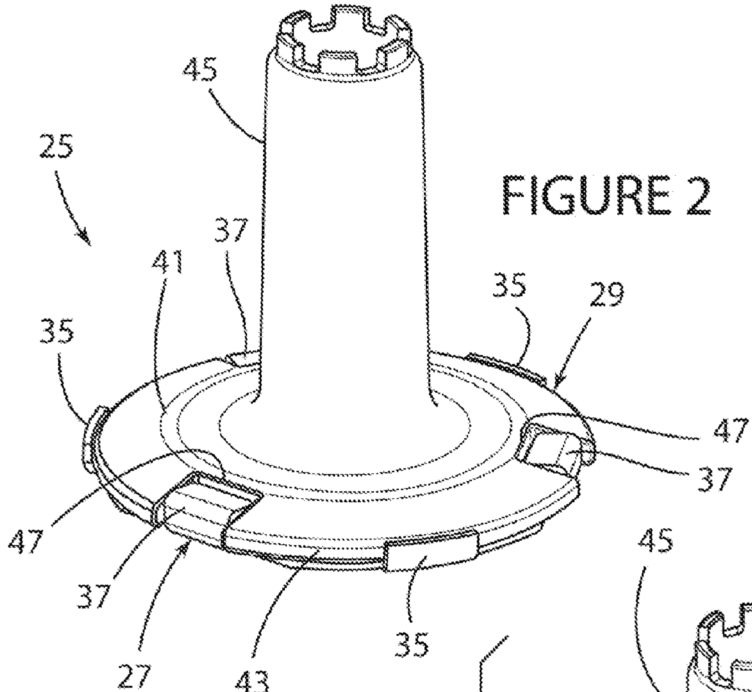
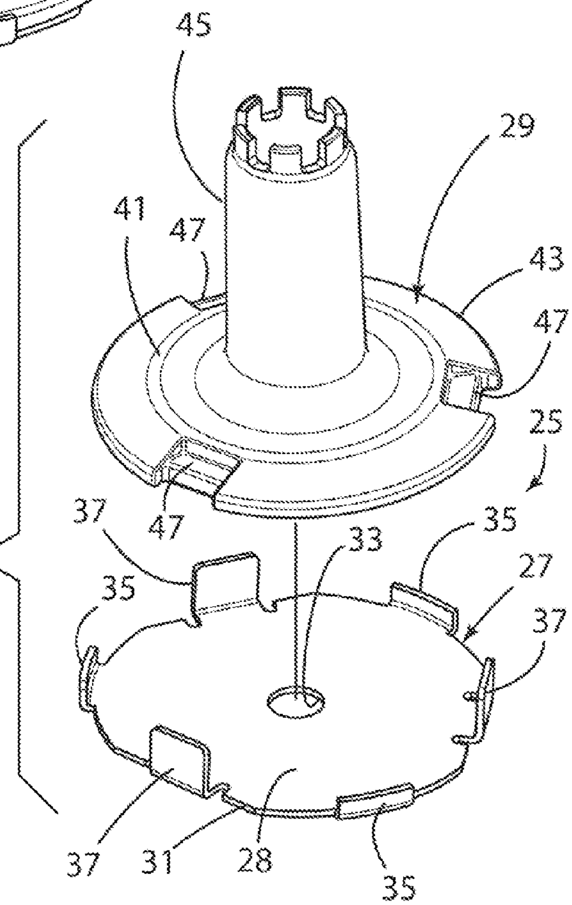


FIGURE 2



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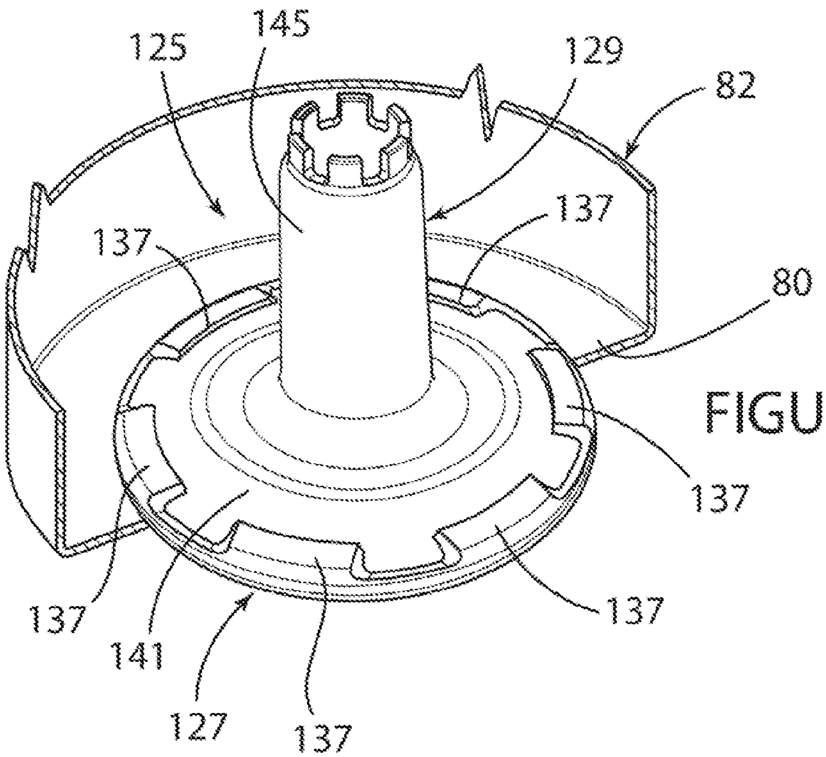
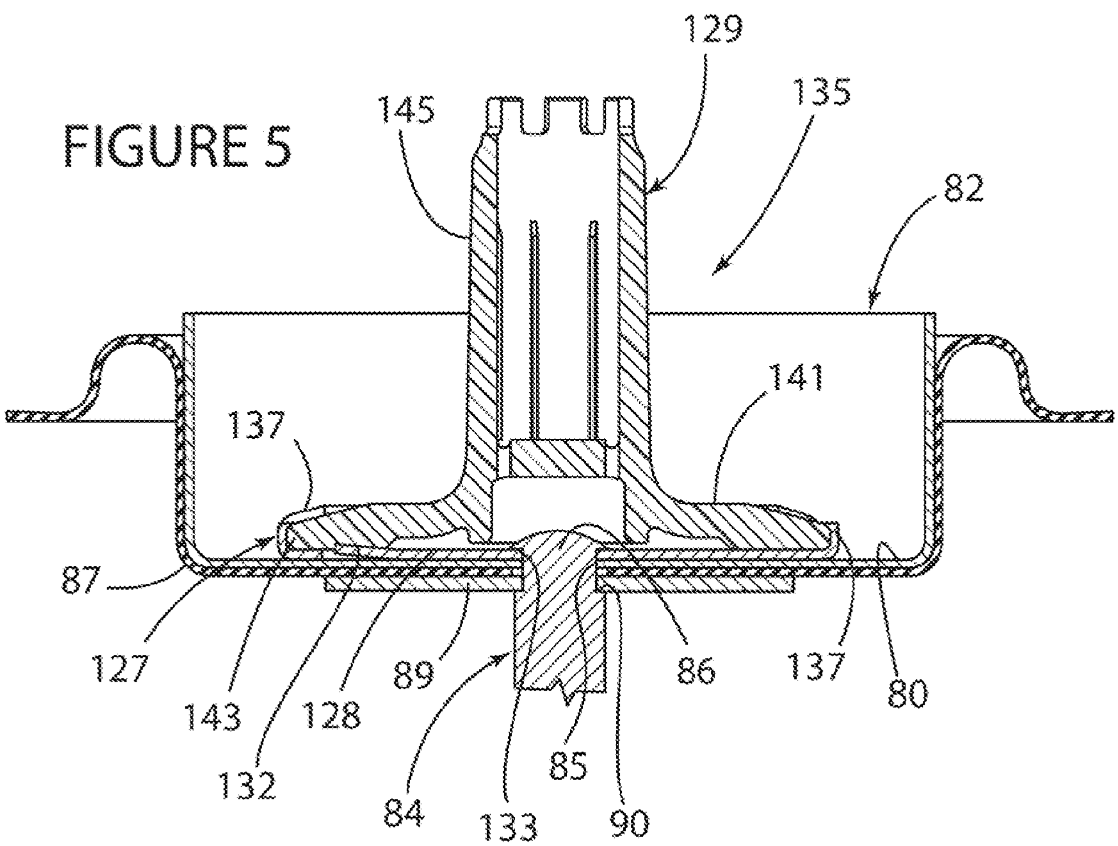


FIGURE 4

FIGURE 5



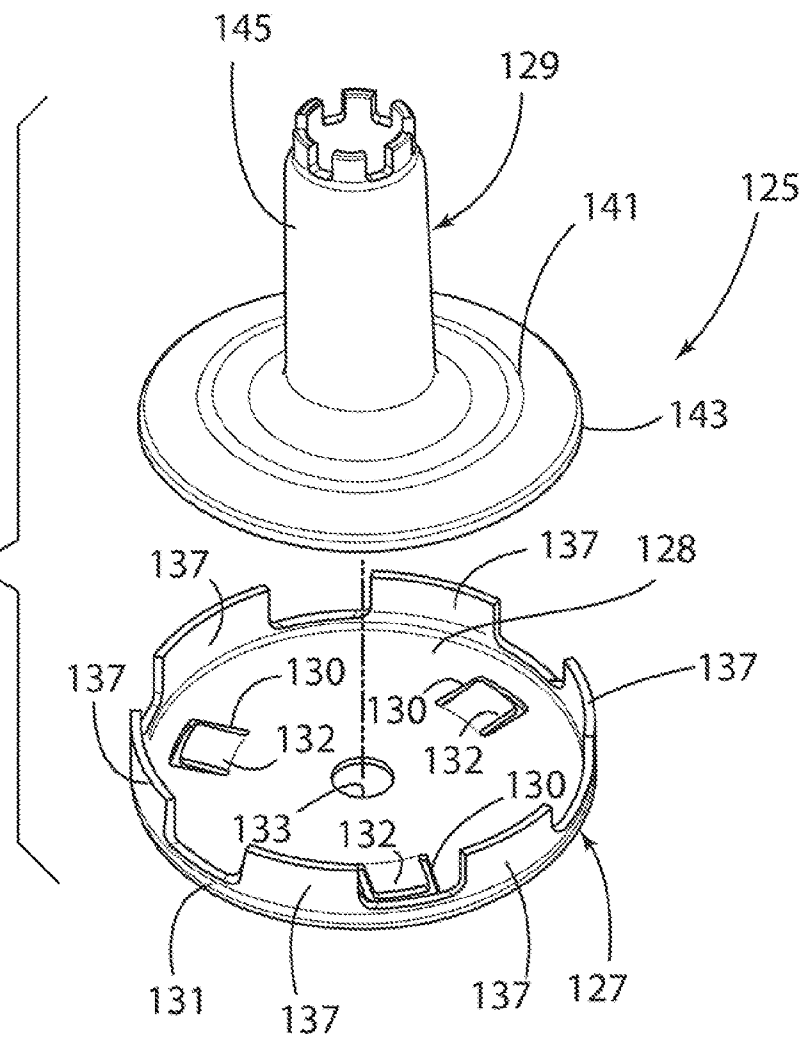

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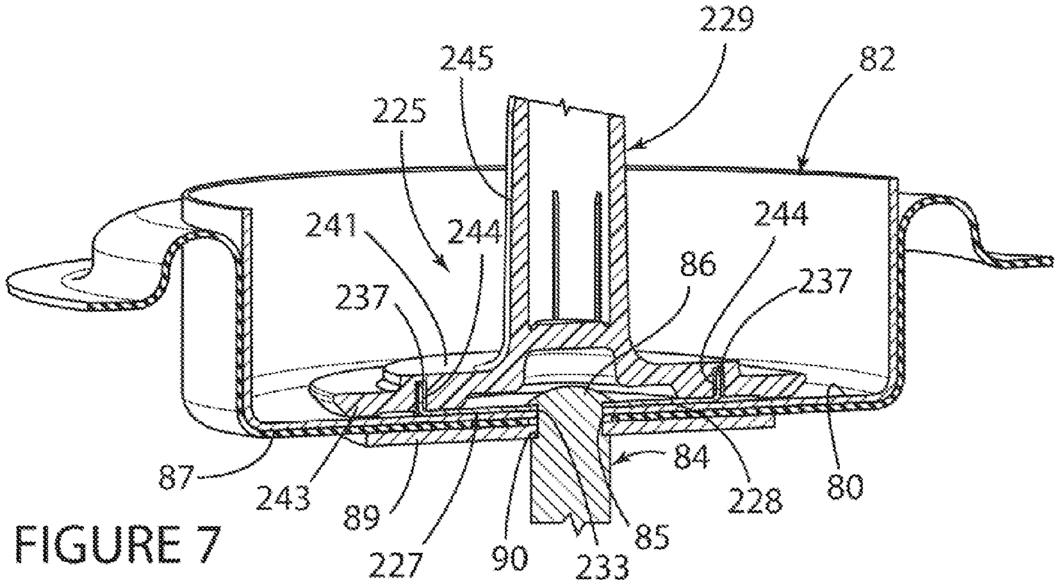
FIGURE 6



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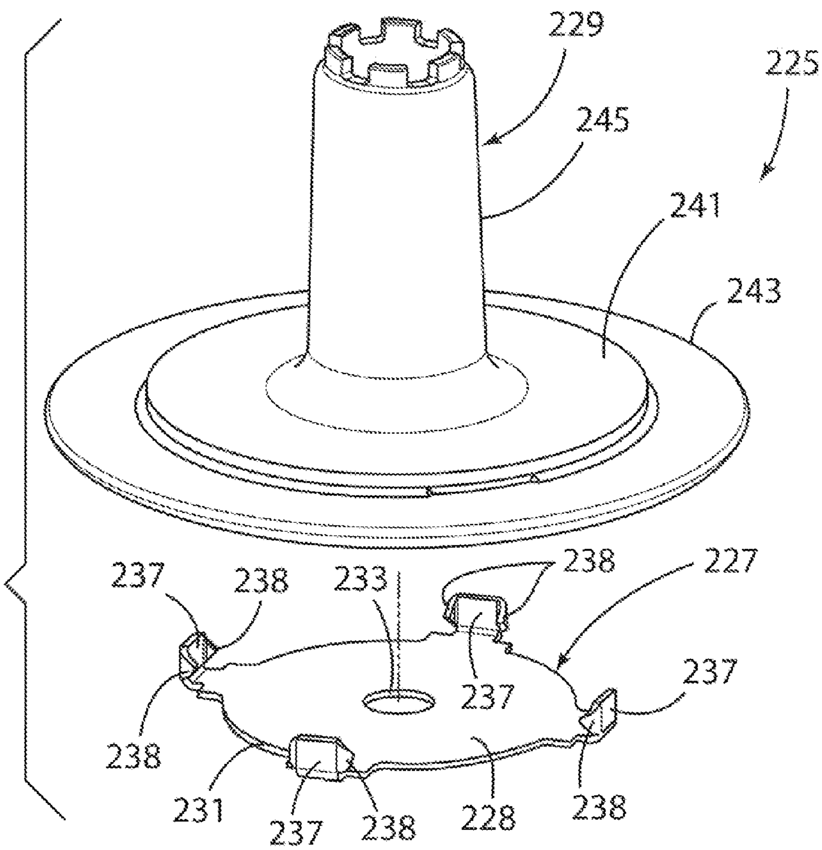

FIGURE 8

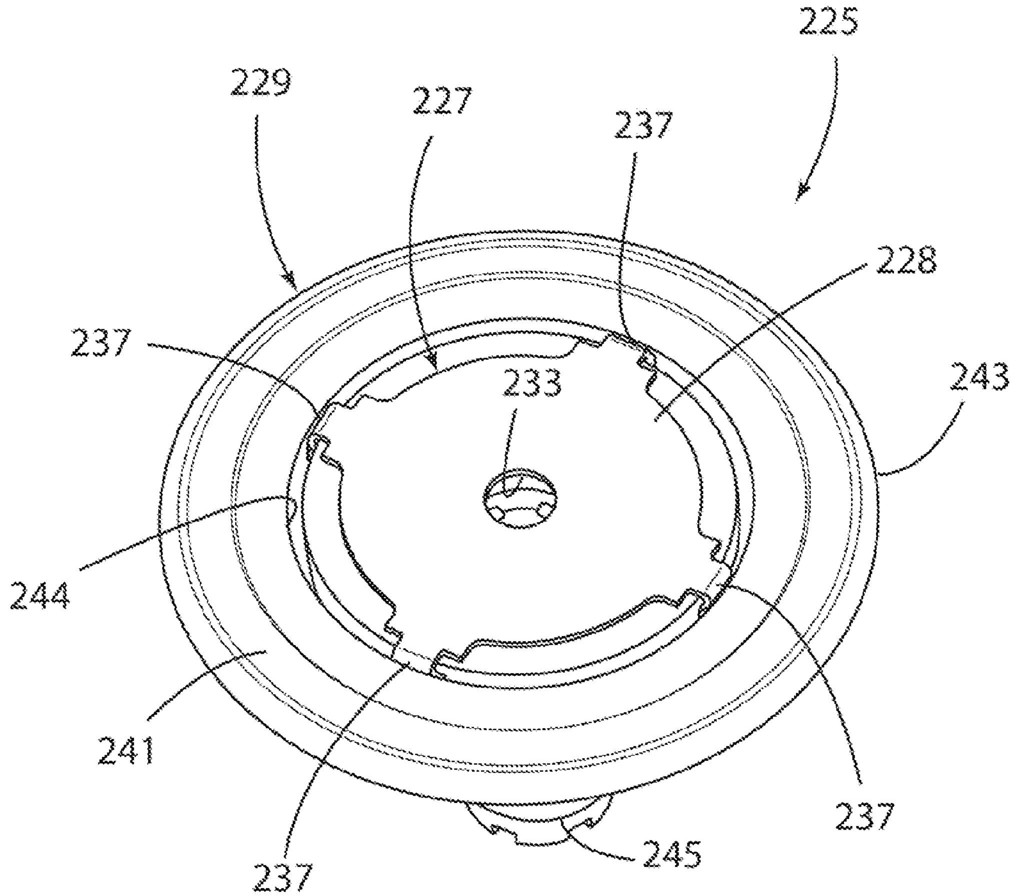

FIGURE 9

FIGURE 10

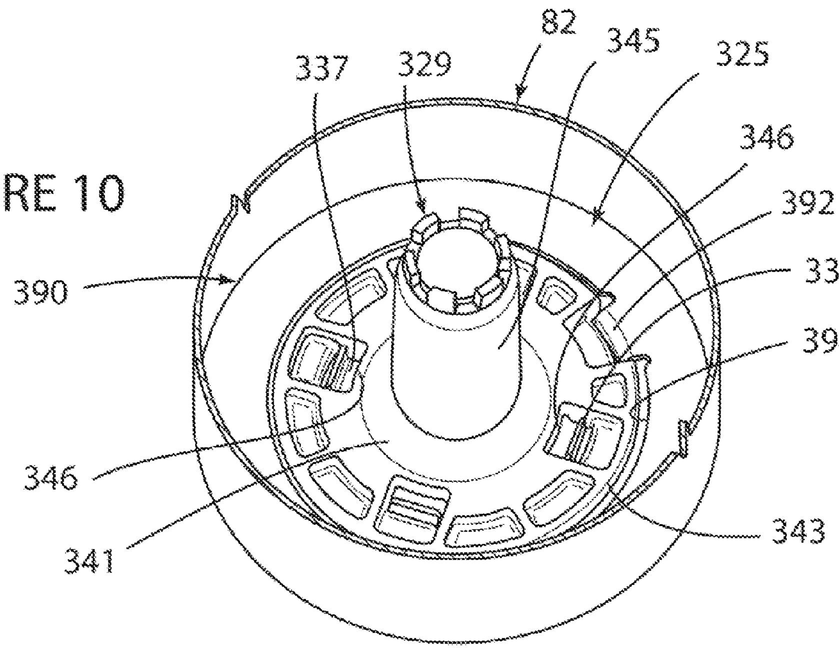

FIGURE 11

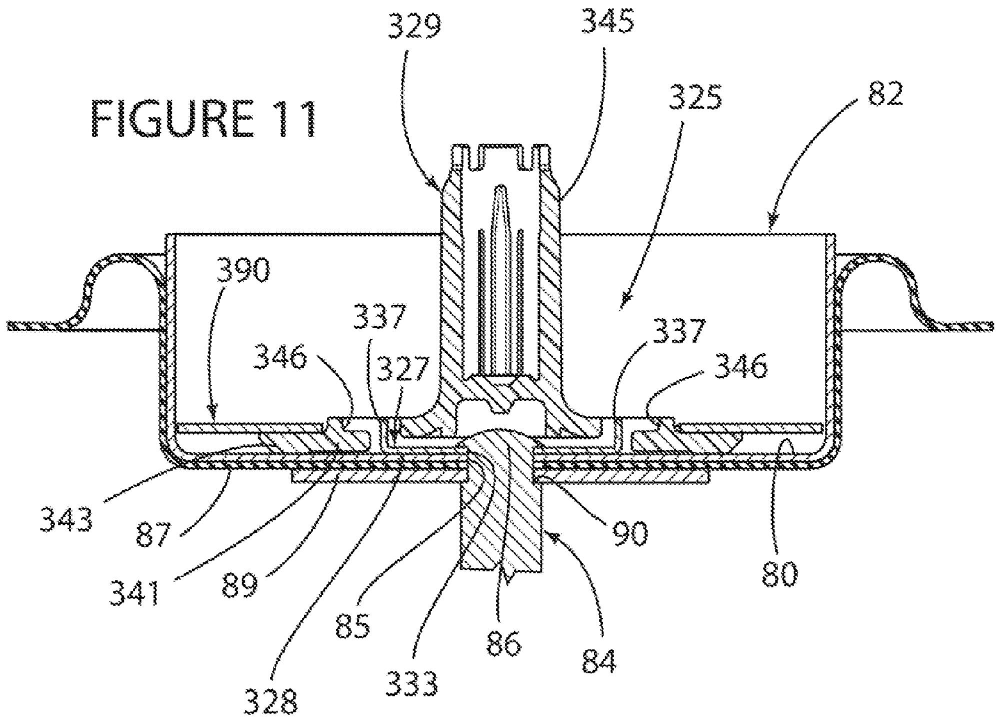

FIGURE 12

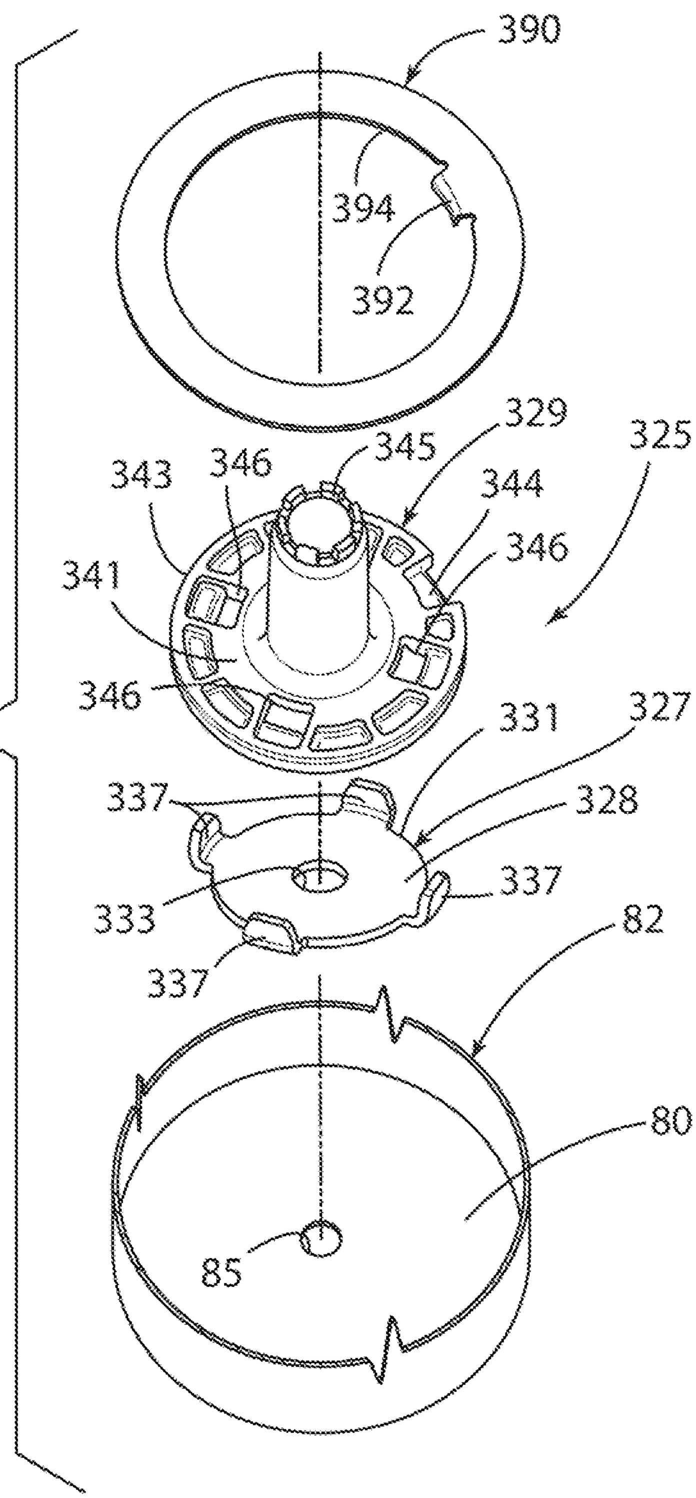
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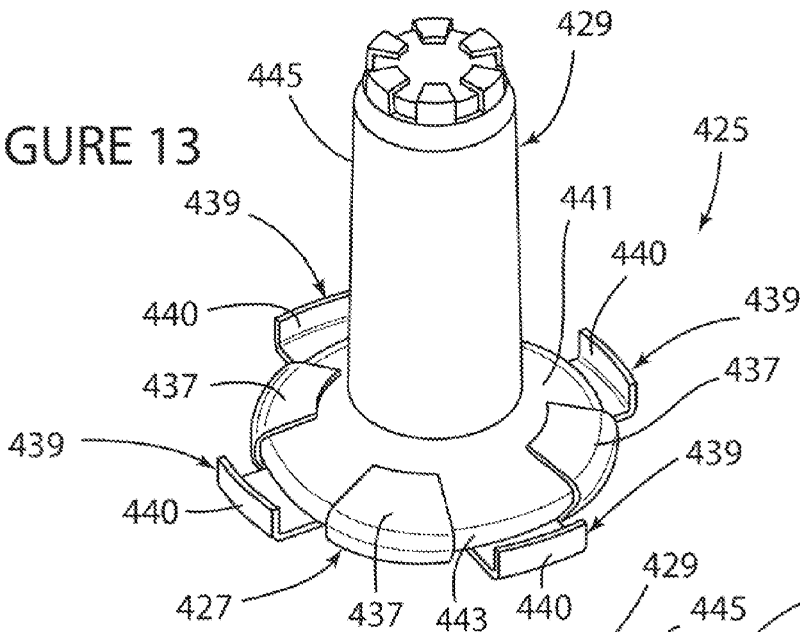
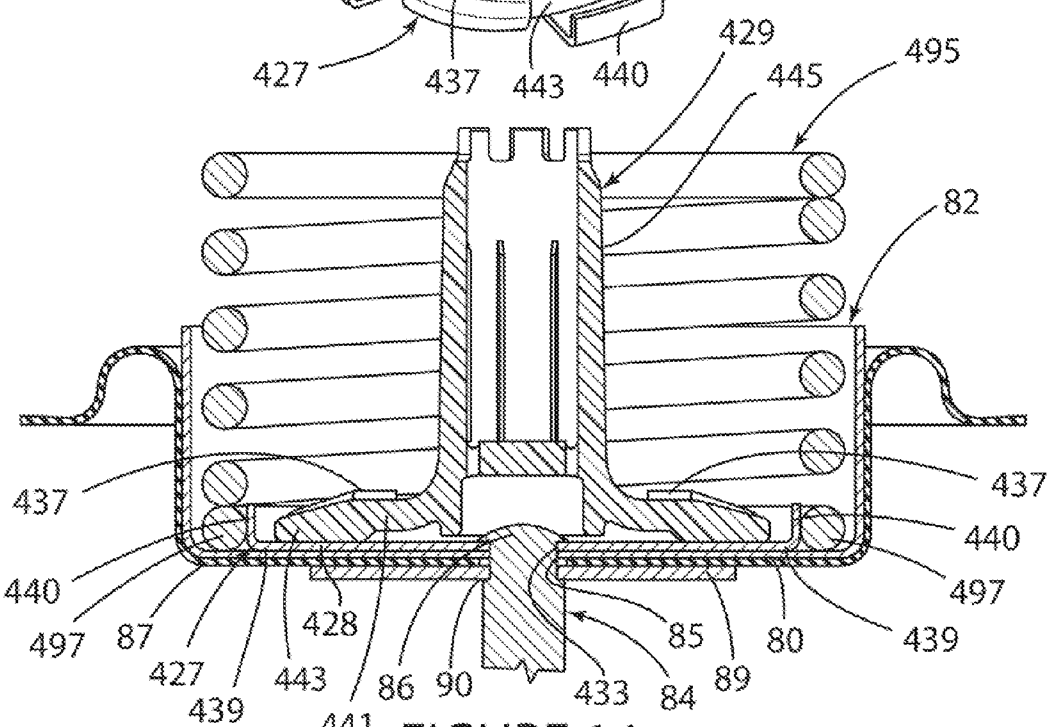
FIGURE 13





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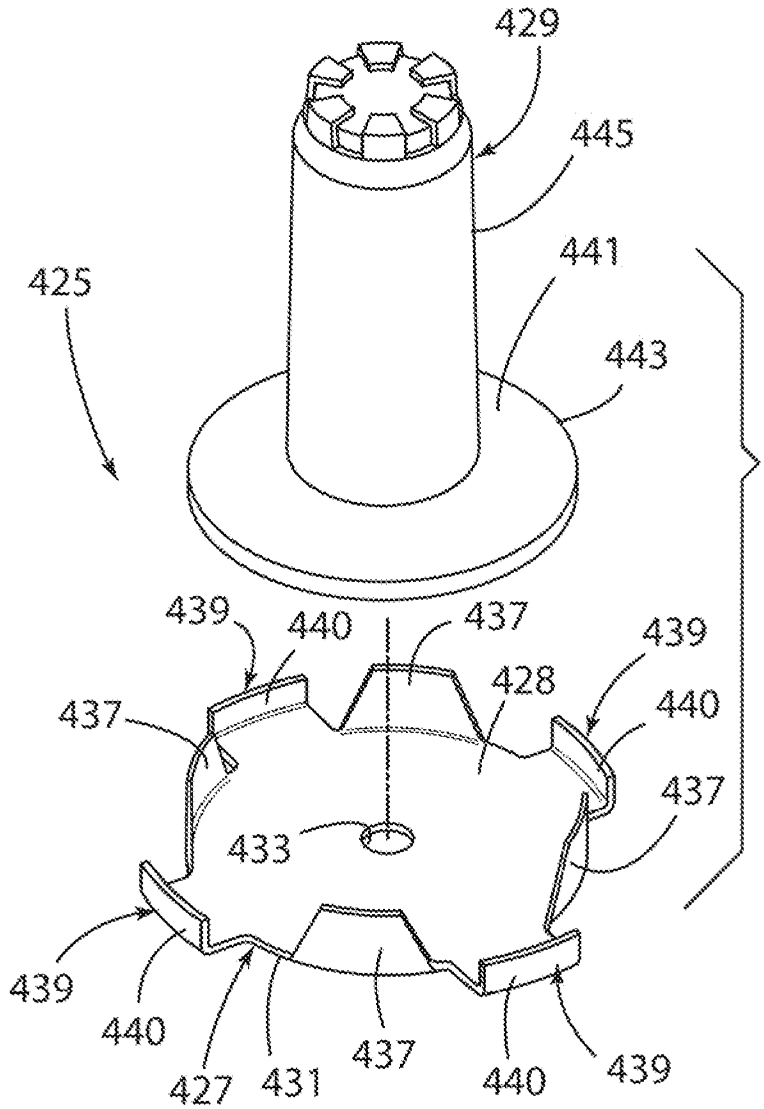
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FIGURE 15

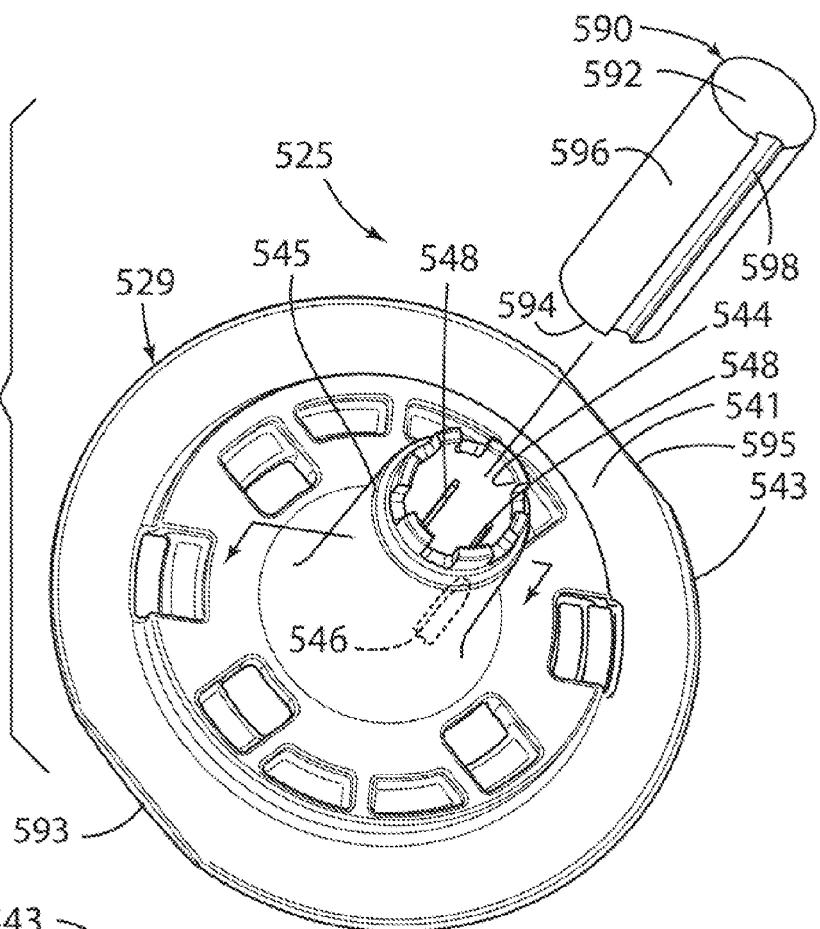

FIGURE 16

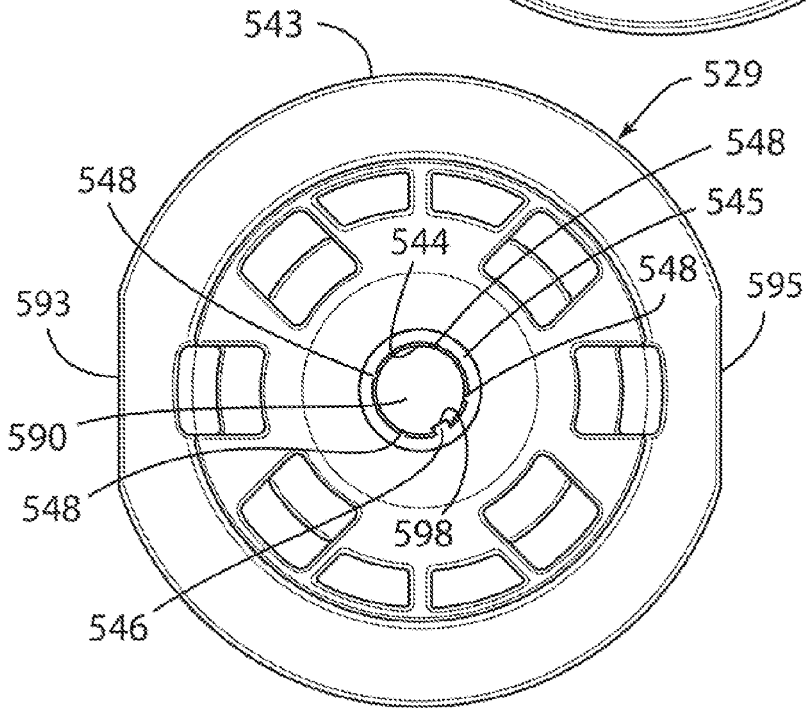

FIGURE 17

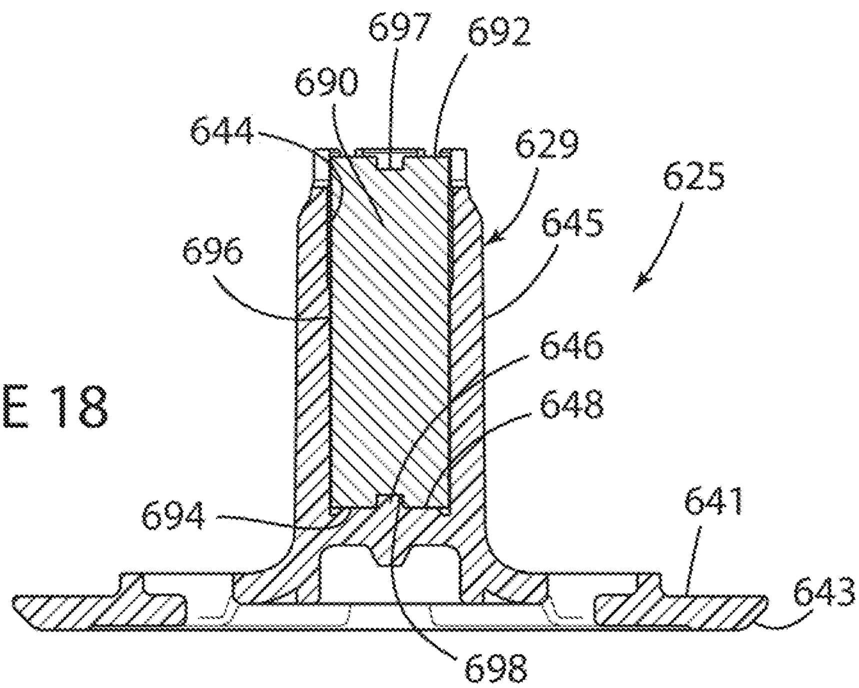

FIGURE 18

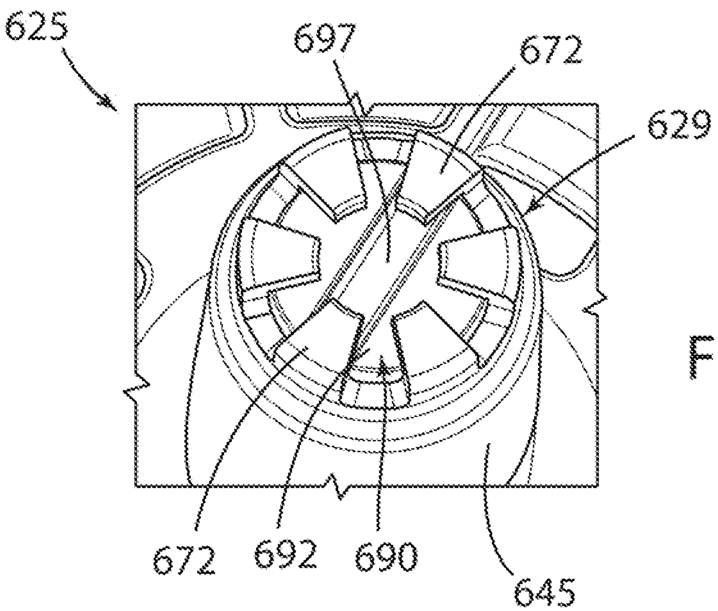

FIGURE 19

LINEAR POSITION SENSOR WITH ANTI-ROTATION DEVICE

CROSS-REFERENCE TO RELATED AND CO-PENDING APPLICATIONS

This application is a continuation application which claims the benefit of U.S. patent application Ser. No. 12/592,170 filed on Nov. 20, 2009, now U.S. Pat. No. 8,400,142 issued on Mar. 19, 2013, entitled Linear Position Sensor with Anti-Rotation Device, the disclosure of which is explicitly incoporated herein by reference, as are all references cited therein, which claims the benefit of the filing date of U.S. Provisional Patent Application Ser. No. 61/200,244 filed on Nov. 26, 2008, the contents of which are explicitly incorporated by reference, as are all references cited therein.

FIELD OF THE INVENTION

This invention relates in general to linear position sensors and, more specifically, to devices to prevent the rotation of the magnet used in a non-contacting linear position sensor.

BACKGROUND OF THE INVENTION

Position sensing is used to electronically monitor the position or movement of a mechanical component. The position sensor produces an electrical signal that varies as the position of the component in question varies. Electrical position sensors are included in many products. For example, position sensors allow the status of various automotive components to be monitored and controlled electronically.

A position sensor needs to be accurate, in that it must give an appropriate electrical signal based upon the position measured. If inaccurate, a position sensor may hinder the proper evaluation and control of the position of the component being monitored.

Typically, it is also a requirement that a position sensor be adequately precise in its measurement. However, the precision needed in measuring a position will obviously vary depending upon the particular circumstances of use. For some purposes, only a rough indication of position is necessary; for instance, an indication of whether a valve is mostly open or mostly closed. In other applications, more precise indication of position may be needed.

A position sensor should also be sufficiently durable for the environment in which it is placed. For example, a position sensor used on an automotive valve may experience almost constant movement while the automobile is in operation. Such a position sensor should be constructed of mechanical and electrical components adequate to allow the sensor to remain sufficiently accurate and precise during its projected lifetime, despite considerable mechanical vibrations and thermal extremes and gradients.

In the past, position sensors were typically of the "contact" variety. A contacting position sensor requires physical contact to produce the electrical signal. Contacting position sensors typically consist of potentiometers that produce electrical signals which vary as a function of the component's position. Contacting position sensors are generally accurate and precise. Unfortunately, the wear due to contact during movement has limited their durability. Also, the friction resulting from the contact can degrade the operation of the component. Further, water intrusion into a potentiometric sensor can disable the sensor.

One advancement in sensor technology has been the development of non-contacting position sensors. A non-contacting position sensor ("NPS") does not require physical contact between the signal generator and the sensing element. Instead, an NPS utilizes magnets to generate magnetic fields that vary as a function of position, and devices to detect varying magnetic fields to measure the position of the component to be monitored. Often, a Hall effect device is used to produce an electrical signal that is dependent upon the magnitude and polarity of the magnetic flux incident upon the device. The Hall effect device may be physically attached to the component to be monitored and thus moves relative to the stationary magnet(s) as the component moves. Conversely, the Hall effect device may be stationary with the magnet(s) affixed to the component to be monitored. In either case, the position of the component to be monitored can be determined by the electrical signal produced by the Hall effect device.

The use of an NPS presents several distinct advantages over the use of a contacting position sensor. Because an NPS does not require physical contact between the signal generator and the sensing element, there is less physical wear during operation, resulting in greater sensor durability. The use of an NPS is also advantageous because the lack of any physical contact between the items being monitored and the sensor itself results in reduced drag.

While the use of an NPS presents several advantages, there are also several disadvantages that must be overcome in order for an NPS to be a satisfactory position sensor for many applications. Irregularities or imperfections in the magnet can compromise the precision and accuracy of an NPS. The accuracy and precision of an NPS can also be affected by the mechanical vibrations and perturbations likely to be experienced by the sensor which, in turn, can cause the magnet or magnet carrier to rotate. Because there is no physical contact between the item to be monitored and the sensor, it is possible for the magnet or magnet carrier to be knocked out of alignment as a result of such vibrations and perturbations. A misalignment or rotation of the magnet relative to the sensor can result in the measured magnetic field at any particular location not being what it would be in the original alignment. Because the measured magnetic field can be different than that when properly aligned, the perceived position can be inaccurate. Linearity of magnetic field strength and the resulting signal is also a concern.

SUMMARY OF THE INVENTION

The present invention is directed broadly to a linear position sensor which comprises a housing, a magnet carrier located in the housing, a magnet located in the magnet carrier, and several different embodiments of anti-rotation means or devices associated with the magnet carrier for preventing the rotation of the magnet outside of allowable variations in rotational movement and eliminating the risk of undesired magnetic field measurements and incorrect sensor signal outputs.

More specifically, in one embodiment, the magnet carrier includes a base having at least one receptacle defined therein and the anti-rotation means comprises an anti-rotation plate which is coupled to the housing and the magnet carrier and the magnet carrier includes at least one finger which extends into the receptacle in the base of the magnet carrier to prevent the rotation of the magnet carrier and thus the rotation of the magnet.

In one embodiment, the base of the magnet carrier includes a peripheral edge and the receptacle is defined by a groove formed in the peripheral edge of the magnet carrier.

In another embodiment, the base of the magnet carrier includes a lower surface and the receptacle is defined by a groove formed in the lower surface of the magnet carrier. The groove may be a circumferentially extending slot formed in the lower surface of the magnet carrier.

In a further embodiment, the base of the magnet carrier includes opposed upper and lower surfaces and the receptacle is defined by a through-hole which extends between the upper and lower surfaces of the magnet carrier.

In yet another embodiment, the anti-rotation plate includes at least one interior slot formed therein which defines the finger and the finger is adapted to abut and exert a force against the lower surface of the base of the magnet carrier.

In yet a further embodiment, the magnet carrier includes a magnet housing having an interior surface with a key defined by a projection and the anti-rotation means comprises a groove in the magnet. The projection in the magnet carrier extends into the groove in the magnet to prevent the rotation of the magnet. The projection may be formed in an interior side surface of the magnet housing and the groove may be defined in an exterior side surface of the magnet. Alternatively, the projection may be formed in an interior base surface of the magnet housing and the groove may be defined in an exterior bottom surface of the magnet. Still further, the magnet housing may include at least one prong extending from a peripheral top edge thereof and another groove may be defined in an exterior top surface of the magnet and the prong extends into the groove in the exterior top surface of the magnet.

There are other advantages and features of this invention which will be more readily apparent from the following detailed description of the embodiments of the invention, the drawings, and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features of the invention can best be understood by the following description of the accompanying drawings as follows:

FIG. **1** is a part vertical cross-sectional view, part perspective view of a linear position sensor with a first embodiment of a magnet carrier/anti-rotation plate combination or device in accordance with the present invention;

FIG. **2** is an enlarged perspective view of the magnet carrier/anti-rotation plate combination shown in FIG. **1**;

FIG. **3** is an enlarged exploded perspective view of the magnet carrier and anti-rotation plate shown in FIGS. **1** and **2**;

FIG. **4** is an enlarged broken perspective view of a second embodiment of a magnet carrier/anti-rotation plate combination in accordance with the present invention;

FIG. **5** is an enlarged vertical cross-sectional view of the magnet carrier/anti-rotation plate embodiment of FIG. **4** coupled to the base in the interior of a linear position sensor as shown in FIG. **1**;

FIG. **6** is an enlarged exploded perspective view of the magnet carrier and anti-rotation plate combination shown in FIGS. **4** and **5**;

FIG. **7** is an enlarged broken part vertical cross-sectional view, part perspective view of a third embodiment of a magnet carrier/anti-rotation plate combination in accordance with the present invention coupled to the base in the interior of a linear position sensor as shown in FIG. **1**;

FIG. **8** is an enlarged exploded perspective view of the magnet carrier and anti-rotation plate shown in FIG. **7**;

FIG. **9** is an enlarged bottom perspective view of the magnet carrier/anti-rotation plate combination shown in FIGS. **7** and **8**:

FIG. **10** is an enlarged top broken perspective view of another embodiment of a magnet carrier/anti-rotation plate combination in accordance with the present invention coupled to the base in the interior of a linear position sensor as shown in FIG. **1**;

FIG. **11** is an enlarged vertical cross-sectional view of the magnet carrier/anti-rotation plate combination of FIG. **10**;

FIG. **12** is a broken exploded perspective view of the magnet carrier and anti-rotation plate combination of FIG. **10**;

FIG. **13** is an enlarged perspective view of yet another magnet carrier/anti-rotation plate combination in accordance with the present invention;

FIG. **14** is an enlarged broken vertical cross-sectional view of the magnet carrier/anti-rotation plate combination of FIG. **13** coupled to the base in the interior of a linear position sensor as shown in FIG. **1**;

FIG. **15** is an enlarged exploded perspective view of the magnet carrier and anti-rotation plate combination shown in FIGS. **13** and **14**;

FIG. **16** is an enlarged exploded perspective view of a magnet carrier/anti-rotation magnet combination in accordance with the present invention;

FIG. **17** is an enlarged horizontal cross-sectional view of the magnet carrier/anti-rotation magnet combination of FIG. **16** with the anti-rotation magnet secured in the magnet carrier;

FIG. **18** is an enlarged vertical cross-sectional view of another embodiment of a magnet carrier/anti-rotation magnet combination in accordance with the present invention; and

FIG. **19** is an enlarged broken top perspective view of the magnet carrier/anti-rotation magnet combination of FIG. **18**.

DETAILED DESCRIPTION OF THE EMBODIMENTS

A first embodiment of an anti-rotation magnet carrier/anti-rotation plate assembly or device or combination **25** in accordance with the present invention is shown in FIGS. **1**-**3** which comprises an anti-rotation disc or plate **27** and a magnet carrier **29**.

Anti-rotation disc or plate **27** has a circular solid base **28**, an outer circumferentially extending peripheral edge **31**, a central through-hole or aperture **33**, and a plurality of tabs or fingers **35** and **37** projecting outwardly and upwardly away from the peripheral edge **31** and extending around the base **28** in a spaced-apart, equidistant, and alternating relationship. Anti-rotation disc or plate **27** can be stamped from sheet metal. The tabs or fingers **35** are wider and shorter than the tabs or fingers **37**.

Magnet carrier **29** has a generally circular base **41** with a circumferentially extending outer peripheral edge **43**; a vertical, hollow magnet tube or housing **45** extending generally normally upwardly from a central portion of the base **41**; and a plurality of receptacles in the form of recesses, grooves, notches, or slots **47** which are formed in the peripheral edge **43** and extend around the base **41** in a spaced-apart, equidistant relationship. Magnet carrier **29** may be made from any suitable thermoplastic material.

As shown in FIG. **1**, anti-rotation disc or plate **27** is seated flat against the base plate **80** of a cup **82** located in the interior of linear position sensor **10** in a relationship wherein the central aperture **33** in anti-rotation plate **27** is in alignment with a central aperture **85** defined in the base plate **80** of cup **82** of linear position sensor **10**. Linear position sensor **10** additionally comprises an elongate, generally cylindrically-shaped shaft **84** which extends through the aligned apertures **33** and **85** in the plate **27** and base **80** respectively. The shaft **84** includes a head **86** having a width greater than the diameter of the shaft **84** and a circumferential recess or groove defined in the outer surface on the shaft **84** below the head **86** which defines a shoulder **90** spaced from the head **86**. The anti-rotation plate **27** and base **80** together with a portion of a membrane **87** located below the base **80** and another plate **89** located below the membrane **87** are sandwiched between the head **86** and the shoulder **90** of shaft **84** to clamp the plate **27** to the base **80** of the cup **82** and keep the plate **27** from moving or rotating relative to the cup **82**.

As shown in FIGS. **1** and **2**, magnet carrier **29** is seated over the anti-rotation plate **27** in a relationship wherein the lower face of the base **41** of magnet carrier **29** is seated in abutting relationship against the upper face of the base **28** of anti-rotation plate **27**; the peripheral edge **43** of the base **41** of magnet carrier **29** is abutted against the interior face of each of the tabs **35** on the base **28** of anti-rotation plate **27**; and fingers **37** are aligned with the notches **47**. The fingers **37** are bent inwardly from their FIG. **3** positions to their crimped FIGS. **1** and **2** positions in which the fingers **37** are located in the respective notches **47** and abutted against surface **41** of magnet carrier **29** to prevent the magnet carrier **29** from rotating relative to the plate **27** which, in turn, prevents the magnet **100** (FIG. **1**) in magnet carrier **29** from rotating relative to the sensor **102** (FIG. **1**) outside of allowable variations of rotational movement to eliminate the risk of unacceptable deviations in the signal generated by the sensor **102**. This, of course, is important inasmuch as any deviations in the rotational movement of magnet **100** from the magnet's original programmed state can induce undesired magnetic field variations and cause incorrect signal outputs.

Another embodiment of anti-rotation assembly **125** in accordance with the present invention is shown in FIGS. **4-6**.

Anti-rotation assembly **125** comprises an anti-rotation disc or plate **127** and a magnet carrier **129**. Anti-rotation disc or plate **127** has a circular solid base or plate **128**, an outer circumferentially extending edge **131**, a central aperture **133**, and a plurality of tabs **137** projecting outwardly and upwardly from the edge **131** of plate **127** and extending around the base **128** in equidistant, spaced-apart relationship. The base **128** additionally defines a plurality of interior spaced-apart, equidistant, generally U-shaped slots **130** defining a plurality of circumferentially extending interior raised pre-stressed prongs, tabs, or fingers **132**. Anti-rotation disc or plate **129** can be stamped from sheet metal.

Magnet carrier **129**, which may be made from any suitable thermoplastic material, includes a generally circular base **141** having an outer circumferentially extending peripheral edge **143** and a central generally cylindrical, hollow magnet tube or housing **145** extending upwardly from the center of the base **141**.

As shown in FIG. **5**, anti-rotation disc or plate **127** is seated on the base **80** of the cup **82** in the interior of linear position sensor **10** and the shaft **84** secures the plate **127** against rotational movement relative to the base **80** in the same manner as the plate **27** of anti-rotation assembly **25**, and thus the earlier description with reference to the attachment of the plate **27** of assembly **25** to the base **80** is incorporated herein by reference.

As shown in FIGS. **4** and **5**, the bottom face or surface of the base **141** of magnet carrier **129** is seated against the upper face or surface of the base **128** of plate **127** in a relationship wherein the prongs **132** in the base **128** of plate **127** abut against the bottom surface of the base **141** of magnet carrier **129**. Tabs **137** on the base **141** of magnet carrier **129** are bent and crimped inwardly into abutting relationship with the top face or surface of the base **141** to secure the base **141** and thus the magnet carrier **129** to the plate **127**, thus preventing the rotation of the magnet carrier **129** relative to the plate **127** and the rotation of magnet **100** (FIG. **1**) relative to the sensor **102** (FIG. **1**) outside of allowable variations in rotational movement to eliminate the risk of undesired magnetic field measurements and incorrect sensor signal outputs.

According to this embodiment, the crimp force exerted by the tabs **137** on the base **141** exerts a downward force against the base **141** which, in turn, causes the raised pre-stressed prongs or tabs **137** on plate **127** to flatten out. The pre-stress prongs **137**, however, are also adapted to flex with the thermoplastic material of the base **141** as a result of thermal exposure to reduce the effects of creep and eliminate the rotation of the magnet carrier **129**.

Another embodiment of an anti-rotation assembly **225** in accordance with the present invention is shown in FIGS. **7-9**. Anti-rotation assembly **225** comprises an anti-rotation disc or plate **227** and a magnet carrier **229**.

Anti-rotation disc or plate **227** has a circular base **228**, an outer circumferential peripheral edge **231**, a central aperture **233**, and a plurality of prongs **237** extending outwardly and generally normally upwardly from the peripheral edge **231**. In the embodiment shown, prongs **237** extend around the base **228** in an equidistant, spaced-apart relationship. Each of the prongs **237** has a pair of sharp points **238** that extend generally normally inwardly from opposed sides of each of the prongs **237**. Anti-rotation disc or plate **227** may be stamped from sheet metal.

Magnet carrier **229**, which may be made from any suitable thermoplastic material, has a generally circular base **241** with an outer circumferentially extending peripheral edge **243**; a vertical, cylindrical, hollow magnet or housing tube **245** extending generally upwardly from a central portion of the top surface or face of the base **241**; and an annular circumferentially extending interior receptacle in the form of a slot **244** formed and extending into the bottom surface or face of base **241**.

As shown in FIG. **7**, the plate **227** of anti-rotation assembly **225** is seated on the base **80** of the cup **82** in linear position sensor **10** and is rigidly connected to the shaft **84** of linear position sensor **10** in the same manner as the plate **27** of anti-rotation assembly **25** and thus the earlier description with reference to assembly **25** is incorporated herein by reference.

As shown in FIGS. **7** and **9**, the bottom face or surface of the base **241** of magnet carrier **229** is seated against the upper face or surface of the base **228** of the plate **227** in a relationship wherein the prongs **237** on plate **227** are aligned with and extend into respective portions of the slot **244** in the bottom face or surface of the base **241** of magnet carrier **229**. The sharp points **238** on each of the prongs **237** have a length which is greater than the width of the slot **244** so that the points **238** wedge into the material of the base **241** upon insertion of the prongs **237** in base **241** to secure the magnet carrier **229** to the plate **227** and prevent the rotation of the magnet carrier **229** relative to the plate **227** which, in turn, prevents the rotation of the magnet **100** (FIG. **1**) relative to the sensor **102** (FIG. **1**) outside of allowable variations in rotational movement to eliminate the risk of undesired magnetic field measurements and incorrect sensor signal outputs.

FIGS. **10-12** depict a further embodiment of an anti-rotation assembly **325** in accordance with the present invention which comprises an anti-rotation disc or plate **327** and a magnet carrier **329**.

Anti-rotation disc or plate **327** has a circular base **328**, an outer peripheral circumferential edge **331**, a central aperture **333**, and a plurality of fingers **337** projecting outwardly and generally normally upwardly from the peripheral edge **331** and extending around the base **328** in an equidistant, spaced-apart relationship. Anti-rotation disc or plate **327** may be stamped from sheet metal.

Magnet carrier **329**, which may be made from any suitable thermoplastic material has a generally circular base **341** with an outer peripheral circumferential edge **343**; a vertical, hollow, cylindrical magnet tube or housing **345** extending normally upwardly from the center of the top surface of the base **341**; at least one receptacle in the form of a recess, groove, notch, or slot **344** formed in the peripheral edge **343** of base **341**; and a plurality of interior receptacles in the form of through-holes or openings **346** defined in the base **341** and extending between the top and bottom surfaces thereof. Through-holes **346** extend around the base **341** in an equidistant, spaced-apart relationship.

As shown in FIG. **11**, anti-rotation disc or plate **327** is seated on the base **80** of the cup **82** in linear position sensor **10** and the shaft **84** of linear position sensor **10** couples and secures the plate **327** to the cup **82** in the same manner as described earlier with respect to the plate **27** of anti-rotation assembly **25**, and thus the earlier description with reference to plate **27** is incorporated herein by reference.

As shown in FIGS. **10** and **11**, magnet carrier **329** is located and seated in the interior of the cup **82** of linear position sensor **10** in a relationship wherein the bottom face or surface of the base **341** of magnet carrier **329** is seated against the upper face or surface of the base **328** of the plate **327** in a relationship wherein the fingers **337** on plate **327** are aligned with and extend through respective ones of the through-holes **346** defined in the base **329** of magnet carrier **341** to prevent the rotation of the magnet carrier **329** relative to the plate **327** and thus prevent the rotation of magnet **100** (FIG. **1**) relative to the sensor **102** (FIG. **1**) outside of allowable variations in rotational measurement to eliminate the risk of undesired magnetic field measurements and incorrect sensor signal outputs.

As also shown in FIGS. **10-12**, linear position sensor **10** additionally comprises an annular outer ring **390** including a tab **392** which extends generally normally outwardly and downwardly from an interior peripheral circumferential edge **394** of ring **390**.

Ring **390** is seated in the cup **82** of linear position sensor **10** in a relationship surrounding and abutting against the top surface of the peripheral circumferential edge **343** of the base **341** of magnet carrier **329** with the tab **392** seated in the groove **344** defined in the edge **342** of the base **341** of magnet carrier **329** to prevent the rotation of the ring **390** relative to the magnet carrier **329** and the cup **82**.

FIGS. **13-15** depict yet a further embodiment of an anti-rotation assembly **425** in accordance with the present invention which comprises an anti-rotation disc or plate **427** and a magnet carrier **429**.

Anti-rotation disc or plate **427** has a circular base **428**, an outer peripheral circumferential edge **431**, a central aperture **433**, a plurality of crimp tabs **437** projecting outwardly and upwardly from the peripheral edge **431**, and a plurality of elongate legs **439** also extending outwardly from the peripheral edge **431**. The fingers **437** and legs **439** extend around the base **428** in a spaced-apart and alternating equidistant relationship. The tabs **437** are shown in FIG. **15** in their uncrimped position and orientation generally normal to the base **428** of plate **427**. The legs **439** extend outwardly from the peripheral edge **431** of plate **427** in a relationship generally co-planar with the base **429**. Each of the legs **439** includes a distal upturned ear **440** extending generally normally upwardly from the distal end of each of the legs **439**.

Magnet carrier **429** has a generally circular base **441** with an outer peripheral circumferential edge **443**, and a vertical, hollow, cylindrical magnet tube or housing **445** extending generally normally upwardly from the center of the base **441**.

As shown in FIG. **14**, the plate **427** is seated and secured to the base **80** of the cup **82** in the interior of linear position sensor **10** and the shaft **84** couples and secures the plate **427** to the cup **82** in the same manner as described earlier with respect to the plate **27** of anti-rotation assembly **25** and thus the earlier description with reference to the plate **27** and assembly **25** is incorporated herein by reference.

As additionally shown in FIG. **14**, the exterior face of each of the ears **440** of the legs **439** of the plate **427** is positioned in abutting relationship with and against the interior face of one of the coils **497** of helical spring **495** which is also located in the interior of the linear position sensor **10** and seated on the base **80** of the cup **82** in linear position sensor **10** to provide for the concentric positioning and compression of the spring **495** in linear position sensor **10** and eliminate the risk of collision and controlling axial force compression in the interior of linear position sensor **10**.

As shown in FIG. **14**, magnet carrier **429** is located and seated in the interior of linear position sensor **10** in a relationship wherein the lower face or surface of the base **441** of magnet carrier **429** is seated against the upper face or surface of the base **428** of plate **427**; the tube **445** is co-linearly aligned with the shaft **84**; and the peripheral edge **443** of the base **441** of magnet carrier **429** is abutted against the inside face of respective crimp tabs **437** on plate **427**. The tabs **437** are bent inwardly and crimped into abutting relationship with the top surface or face of the base **429** of magnet carrier **429** to secure the magnet carrier **429** to the plate **427**, thus preventing the rotation of the magnet carrier **429** and the rotation of the magnet **100** (FIG. **1**) relative to the sensor **102** (FIG. **1**) outside of allowable variations in rotational movement to eliminate the risk of undesired magnetic field and signal variations as described above.

Although not shown in any of the FIGURES, it is understood that a compression o-ring may be sandwiched between the lower surface of the base **441** of the magnet carrier **429** and the upper surface of the base **428** of the plate **427** to enhance the crimp action and connection between the plate **427** and magnet carrier **429**.

FIGS. **16** and **17** depict an anti-rotation assembly **525** in accordance with the present invention which comprises a magnet carrier **529** and an anti-rotation magnet **590**.

Magnet carrier **529** has a generally circular base **541** with an outer peripheral circumferential edge **543** and a vertical, hollow, cylindrical magnet tube or housing **545** extending generally normally upwardly from the center of the base **541**. In the embodiment of FIGS. **16** and **17**, the peripheral edge **543** of magnet carrier **529** additionally includes a pair of diametrically opposed straight segments **593** and **595** defining a pair of keying features for automated feeding of the magnet carrier **529** during assembly. Tube **545** includes an interior cylindrical surface **544** having a key defined by an elongate projection or bump **546** protruding outwardly therefrom and extending the length of the tube **545** in an orientation generally normal to the base **541**. The interior cylindrical surface **544** of the tube **545** additionally includes a plurality of elongate, spaced-apart, parallel crush ribs **548** projecting outwardly therefrom and extending around the circumference of the interior surface **544** in a relationship spaced from and parallel to the elongate key **546**.

The magnet **590** is in the form of an elongate solid cylinder which includes respective top and bottom surfaces **592** and **594** and a side exterior longitudinal surface **596** having an elongate groove or recess **598** defined therein and extending generally between the top and bottom surfaces **592** and **594**.

As shown in FIG. **17**, magnet **590** is slid into and secured in the interior of the tube **545** in a relationship wherein the key **546** in tube **545** is aligned with and extends and protrudes into the groove **598**. The diameter of the tube **545** and the diameter of magnet **590** are such that the ribs **548** in the tube **545** are crushed when magnet **590** is slid into the tube **545**, thus providing for a friction fit between magnet **590** and tube **545**. The combination of the key **546** in tube **545** and groove **598** in magnet **590** eliminates the risk of any rotation of the magnet **590** relative to the tube **545** outside of allowable variations of rotational movement to eliminate the risk of undesired magnetic field measurements and thus incorrect signal variations as described above.

FIGS. **18** and **19** depict another anti-rotation assembly **625** in accordance with the present invention which comprises a magnet carrier **629** and an anti-rotation magnet **690**.

Magnet carrier **629** has a generally circular base **641** with an outer peripheral circumferential edge **643** and a vertical, hollow, cylindrical magnet tube or housing **645** extending generally normally upwardly from the center of the base **641**. Tube **645** includes an interior cylindrical surface **644** and an interior lower or bottom horizontal base or surface **648** with a key defined by a projection or bump **646** protruding outwardly therefrom.

Magnet **690** is in the form of an elongate solid cylinder which includes respective top and bottom surfaces **692** and **694** and a side exterior longitudinal surface **696**. Each of the top and bottom surfaces **692** and **694** includes an elongate groove **697** and **698** formed therein.

As shown in FIG. **18**, magnet **690** is slid into and secured in the interior of tube **645** in a relationship wherein the bottom surface **694** of magnet **690** is abutted against the bottom interior surface or base **648** of the tube **645** and the key **646** extends and protrudes into the groove **698** defined in the bottom surface **694** of magnet **690**.

As shown in FIG. **19**, the magnet carrier **629** and, more specifically, the tube **645** thereof includes a plurality of prongs **672** extending outwardly and inwardly from a top peripheral edge **674** thereof. Two of the prongs **672** are opposed to each other and are positioned and extend into the groove **697** formed in the top surface **692** of the magnet **690**.

Thus, according to the invention, the use of a key **646**/groove **698** combination and prong **672**/groove **697** combination eliminates the risk of rotation of the magnet **690** relative to the tube **645** outside of allowable rotational variations to again eliminate the risk of undesired magnetic field and signal variations as described above.

While the invention has been taught with specific reference to the embodiments shown, it is understood that a person of ordinary skill in the art will recognize that changes can be made in form and detail without departing from the spirit and the scope of the invention. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes that come within the meaning and range of equivalency of the claims are to be embraced within their scope.

What is claimed is:

1. A linear position sensor comprising:

a housing;

a magnet carrier located and movable linearly in the housing, magnet carrier including a base;

a magnet on the magnet carrier;

a shaft extending in the housing; and

a plate located in the housing between the shaft and the magnet carrier, the shaft secured to the plate and the plate secured to the base of the magnet carrier, the plate including at least one finger coupled to the base of the magnet carrier for preventing the rotation of the magnet carrier relative to the plate.

2. The linear position sensor of claim **1** wherein a slot is formed in the lower surface of the base of the magnet carrier, the at least one finger on the plate extending into the slot.

3. A linear position sensor comprising:

a housing;

a magnet carrier located and adapted for linear movement in the housing, the magnet carrier including a base;

a magnet located on the magnet carrier;

a cup located and adapted for linear movement in the housing, the base of the magnet carrier being seated in the cup;

a shaft extending into the housing and coupled to the cup and adapted for linear movement with the cup; and

anti-rotation means for preventing the rotation of the magnet.

4. The linear position sensor of claim **3** wherein the anti-rotation means comprises an anti-rotation plate seated on the cup in the housing and the shaft couples the anti-rotation plate to the cup and the magnet carrier is seated in the cup and against the anti-rotation plate, the anti-rotation plate including at least one finger for coupling the plate to the base of the magnet carrier for preventing the rotation of the magnet carder and the magnet.

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